AD

TECHNICAL REPORT
TR-78-036-FEL

REFERENCES ON COMPRESSION OF FREEZE-DRIED FOODS

Project Reference: 1L162724AH99BB

Approved for public release;
distribution unlimited.

August 1970

UNITED STATES ARMY
NATICK RESEARCH and DEVELOPMENT COMMAND
NATICK, MASSACHUSETTS 01760

Food Engineering Laboratory
FEL-71

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NATICK/TR-78/016	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): REFERENCES ON COMPRESSION OF FREEZE-DRIED FOODS	5. TYPE OF REPORT & PERIOD COVERED: Technical
	6. PERFORMING ORG. REPORT NUMBER: FEL-71
7. AUTHOR(s): S.E. Wallen, J.M. Tuomy and G.C. Walker	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Army Natick Research & Development Command, Natick, Massachusetts 01760	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 1L162724AH99BB
11. CONTROLLING OFFICE NAME AND ADDRESS: Animal Products Group, Food Engineering Lab, US Army Natick Research & Development Command, Natick, Massachusetts 01760	12. REPORT DATE: June 1978
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

FOOD Processing;	FOODS	DATA
FREEZE DRIED FOODS;	FREEZE DRYING;	DOCUMENTS
COMPRESSED FOODS;	REVERSIBLE COMPRESSION; (KT).	
COMPRESSION	REVERSIBLE	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report attempts to assemble the references to the R&D work conducted in the area of freeze-dried and compressed foods. Sixty-eight technical reports with authors summaries, 69 journal articles and papers, 27 patents, and 17 specifications and Limited Production Purchase Descriptions are cited. The works cover the period from 1942 through 1977. In addition, the technical reports are cross-referenced by year of publication, by food category, and by author. The journal articles and papers are cross-referenced by author.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

LIST OF TABLES

PREFACE

The US Army Natick Research and Development Command (NARADCOM) has R&D responsibility for all food consumed by the Armed Services. One of the most important aspects of this responsibility is the R&D on food for operational consumption in situations where the logistics of moving and storing dictate the desirability of nonstandard foods.

Throughout history weight and bulk of food have been of prime concern to the military as well as explorers and frontiersmen. The terms "jerky" and "pemmican" are common in our own history. In the underdeveloped nations dried foods, and particularly dried meat and fish such as charque in South America and biltong in South Africa, are very common since refrigeration is scarce.

After WW II military strategists projected the need for greater mobility of combat troops. This in turn emphasized the need for dehydrated foods. An investigation showed that, while there are many dried foods available such as dried fruits and dry sausage, these products would not constitute a full menu of high acceptability to the American serviceman. It was found that freeze-drying offered the greatest potential of giving dried foods that could be reconstituted to products very similar to the original fresh or frozen counterparts. Therefore, extensive work was started in the 1950's to develop freeze-dried foods for military use.

Freeze-drying decreases the weight of the food, but it does not change its bulk. Therefore, it would be desirable to find ways to compress the dried food so that the volume reduction could match the weight reduction. At the same time the compression should be reversible so that the compressed product will rehydrate back to the original familiar food.

The desirability of reversibly compressed freeze-dried food for military use is such that considerable R&D has been done in the area. This report attempts to assemble the references to this work into one document.

This report was compiled under Project No. 1L162724AH99BB Food Processing and Preservation Techniques.

REFERENCES ON COMPRESSION OF FREEZE-DRIED FOODS

INTRODUCTION

Freeze-drying removes water by sublimation and the resulting dry product has almost the same dimensions as the original wet product. However, the interior looks like a sponge under a microscope with void spaces equivalent to the amount of water removed. With meat the ratio of solids to voids may be around 1 to 4. With vegetables it may go as high as 1 to 20. Thus, if the products could be compressed and then rehydrated back to a familiar product, a volume saving equivalent to the weight saving could be attained still maintaining good quality.

In 1964 Tronchemics Research Inc., working under a contract with NARADCOM, developed a practical method by which freeze-dried foods could be compressed (Report #22, 1965, Technical Reports). Since that time, considerable work has been done to develop various products and methodology. It was decided, therefore, to collect into one report references to work which have been done on freeze-drying and compression of freeze-dried foods.

The reference works are divided into four categories - NARADCOM technical reports, journal articles and papers, patents, and military specifications. With the reports authors' abstracts containing minor changes are given along with the citations. In regard to journal articles, patents, and specifications, only the citations are given.

Originally it was planned to include only references to compressed freeze-dried foods in this report. However, compression is so closely interwoven with freeze-drying that it was decided to include both types, but with emphasis on compression as far as the technical reports are concerned; scientific publications, patents, and military specifications cited are essentially concerned with compression.

Technical Reports

1. Bauman, H.E., Development of bite-size food pieces, Report No. 2 (final). The Pillsbury Co., Contract No. DA 19-129-QM-1937. Quartermaster Food and Container Institute, C-324. December 1961/July 1962. No author abstract available.

2. Blodgett, J. Maximum variety from feeding unit of low weight and bulk. The Pillsbury Co., Contract No. DAAG 17-68-C-0148. 70-29-FL. (FL-103). November 1969 (AD 702959).

This project was originated to: (1) improve organoleptic acceptability and performance of the meal items developed during the course of work on NLABS contract number DA19-129-AMC-860(N), (2) develop 5 dual function food bars and (3) develop coating material and methods of application to prevent fragmentation of the components.

Information is presented for the preparation of 7 improved food bars and 11 improved adjunct cubes, which when combined in defined combinations yield 32 familiar meal items.

Five dual function food bars were also prepared. Dual function bars may be consumed "as is" or hydrated to yield a familiar food item.

Two coatings were prepared that when applied to the food bars and adjunct cubes prevent attrition and fragmentation during handling.

Meal items prepared from the above coated components that had been stored for four months at 38°C in N_2 filled cans were found acceptable when evaluated by a 30-man panel.

Hedonic ratings for the prepared meal items before and after storage along with data on microbiological and moisture changes during storage and data to indicate coating effectiveness are also given.

3. Brown, C.L., Shafer, H.W., and Tuomy, J.M. Effect of freeze-drying conditions on the quality of raw pork. 72-41-FL. (FL-149), February 1972 (AD 739496).

Raw pork chops were freeze-dried using platen temperatures of 100, 125, 150 and 175°F with radiant heat and dehydrator pressures of 0.5, 1.0, 1.5 and 2.0 mm of mercury. The dried products were canned under atmospheric pressure and stored at 40, 70 and 100°F with withdrawals at 2, 4, 8 and 16 weeks. Oxygen uptake, rehydration ratios and the differences between the penetrometer readings on the raw chop and the same chop after processing, storage, and cooking were determined.

Analysis of variance indicated that the dehydrator pressure x platen temperature interaction and either the pressure or the temperature had statistically significant effects on the oxygen uptake, rehydration ratios, and tenderness (penetrometer values). In general, these effects were small in comparison with those resulting from storage temperature and time. However, they must be considered in the overall quality of freeze-dried raw pork. Except for the rehydration ratio, the direction of the better quality was with lower dehydrator pressures and platen temperatures.

4. Chipault, J.R. and Hawkins, J.M. Oxidation changes affecting odor and flavor of freeze-dried meats. University of Minnesota, Contract No. DA19-129-QM-1994. May 1965 (AD 619440).

Samples of commercially-prepared freeze-dried cooked and raw beef, raw pork, raw fish and shrimp have been examined in a Warburg apparatus and their oxygen absorption characteristics have been measured. The moisture content, glyceride fat, and bound lipids have been determined also. The oxidation of these materials appears to be complex. It is a two-step process involving first oxidation of the bound lipids, followed, after a variable period of lower oxygen absorption, by oxidation of the glyceride fat. The rates of oxidation during these two steps and the length of the period of low oxygen absorption between them are determined by the nature and history of the sample.

In these commercially prepared samples of unknown history no correlation could be established between absorption of oxygen and type of product, moisture content, bound lipids, or glyceride fat content.

Large variations in the over-all rates of oxygen absorption were observed between different lots of the same type of material, between different portions of product taken from the same container.

The oxidation of freeze-dried raw tissue appears to be due to autoxidation rather than to enzymatic action.

Samples of raw and cooked freeze-dried beef were prepared in the laboratory. They were fractionated in an atmosphere of pure nitrogen so that the fractions were not exposed to oxygen prior to oxidation studies.

The bound lipids absorb oxygen rapidly, with no induction period, and no peroxides are formed. In contrast, the isolated glyceride fat is much more resistant to autoxidation and shows a long induction period.

Antioxidants added to freeze-dried beef decreases slightly the rate of oxygen absorption by the bound lipids, but their effect is small and they do not introduce a true induction period.

Off-odors which develop rapidly in freeze-dried meat exposed to oxygen are not due to true oxidative rancidity of the glyceride fat. They appear to be due to the oxidative deterioration of the bound lipids and to the formation of stale, putrid-like odors by water-soluble, non-lipid components of the crude bound lipids. This non-lipid fraction develops strong odors on warming but does not absorb oxygen.

Cooking has a tendency to increase organoleptic deterioration and oxygen absorption. Malonaldehyde accompanies odor formation in cooked but not in raw beef.

There is no difference in the rate of deterioration of two different muscles obtained from the same animal.

Moisture appears to be the most important single factor affecting autoxidation of freeze-dried beef. A moisture level of 1% or less is most desirable.

5. Cole, M.S. Edible coatings for dried and compacted foods: Part II. Archer Daniels Midland Co., Contract No. DA 19-129-AMC-102. 66-38-FD (FD-48). May 1966 (AD 634252).

Edible thermoplastic coatings were applied as moisture-oxygen barriers to dry bars representing a wide range of food compositions. A hot-melt curtain coating technique appears commercially feasible for all foods examined; however, coatings so applied failed to withstand storage at a temperature cycling between -18 and +40°C.

6. Durst, J.R. All purpose matrices for compressed food bars. The Pillsbur Co., Contract No. DA 19-129-729-MC2103, 66-1 FD (FD-37). January 1966 (AD 628377

Edible binders have been developed which impart favorable physical properties including cohesiveness to compressed dry foods representing a broad range of chemical compositions. Further experimental effort yielded binders for compressed foods that are acceptable for consumption from the compressed state and that can also be rehydrated to yield a familiar meal item, such as casseroles creamed soups, puddings, thin soups and beverages. These binders do not significantly alter the storage stability of the basic food components.

7. Durst, J.R. Formulation and fabrication of food bars. The Pillsbury Co., Contract No. DA 19-129-QM-1970. 66-69 (FD-39). February 1966 (AD 631996).

Formulation, production and storage studies of food bars made from various cereal products (wheat flakes, oats, rice crispies, and graham crackers, as well as beef, hash, and soup-type bars (split pea, potato flakes), are presented. The basic matrix for the food bars is a stable binder formulated from protein (sodium caseinate), fat (lard flakes), and carbohydrate (sucrose). The binder is spray-dried, admixed with the food component, and compressed into bar form.

8. Durst, J.R. Compressed food components to minimize storage space. The Pillsbury Co., Contract No. DA 19-129-AMC-860 (M 68-22-FL (FL-64). October 1967 (AD 662060).

The study was originated to design, develop, and demonstrate an integrated feeding system based on a specified number of stable food components that can be stored in a limited space and from which can be prepared a variety of nutritious food items. Information is presented for the preparation of 10 food bars, 4 food sheets, and 13 food adjunct cubes. Data are given on these components packed in flexible pouches, some under vacuum, after a thirteen-week storage study. Evaluations were carried out on microbiological, physical, and organoleptic considerations. Hedonic ratings are shown for 45 meals prepared from these components before and after thirteen weeks, storage at 38°C using both a nine-point (5-neutral) scale and a nine-point (3-neutral) scale. Nutritional values of ingredients used are listed.

9. Fitzmaurice, W.J., Helmer, R.L., and Tuomy, J.M. Compressed freeze-dried meatballs and pork sausage links. 70-72FL (FL-104). October 1969 (AD 697748).

Compressed bars have been developed from freeze-dried meatballs and pork sausage links that show promise for use in operational rations. Compression ratios are 1:3.7 for the meatballs and 1:4.5 for the pork sausage links. Rehydration time is about two minutes in hot water.

10. Ginette, L.F. Investigation of drying procedures for compacted food. FMC Corporation, Contract No. DA 19-129-AMC-228. 66-34-FD (FD-46). May 1966 (AD 633267).

Compressed food bars representing protein, carbohydrate, and fat in all proportions likely to be encountered with natural products and adjusted to 15-25 percent moisture were dried in a forced draft air drier under controlled conditions to a residual moisture content below 5 percent. Rates of drying were studied in relation to wet and dry bulb temperatures of the air flow, composition of bars, shape of bars and pressure of compression. Observations were performed to identify the effect of the drying regimen on surface texture, density, migration of fat and soluble components, and organoleptic properties. Conditions for a practical air-drying process were defined.

11. Goffi, E.A. and Tuomy, J.M. Effect of rehydration and cooking parameters on the tenderness of freeze-dried raw pork chops. 73-6-FL (FL-162). May 1972 (AD 48406).

A full factorial study was conducted with freeze-dried raw pork chops in which the chops were rehydrated at three different temperatures (27°, 38°, 49°C), equilibrated before cooking for three periods (0, 4, 24 hours), cooked

by two different methods (fry, bake), and coated in three different ways (none, flour, breading). The cooked products were evaluated for tenderness by a technological taste panel and penetrometer readings and for water retention during cooking.

Analysis of variance indicated that the use of a coating increased the tenderness of the cooked product appreciably without a substantial increase in cooking time and that breading was more effective than flour alone. Rehydration water temperature and cooking methods had statistically significant effects on the tenderness, but accounted for only small percentages of the total variance observed. Rehydration equilibration time was not statistically significant. Water retained in the product during cooking was linearly correlated with tenderness ($r = 0.5$).

12. Gorfein, H., Rahman, A.R., Powers, E.M. and Westcott, D.E. Dehydrated soups for USAF aircraft. 74-49 (FL-187). March 1974 (AD 780813).

Laboratory tests were conducted on dehydrated soups as a result of a request by the Air Force for the development of soups for use aboard aircraft operating above 15,000 meters (50,000 feet). These tests involved storage studies on seven different commercially available soups after repacking in flexible packages under vacuum. All seven soup products were rehydratable in 66°C water and remained relatively stable when stored at 21°C for one year. All soups packed under vacuum were acceptable in all quality characteristics when stored for three months at 37.8°C. None of the soups had acceptable flavor when stored for six months and twelve months at 38°C. Thiobarbituric acid (TBA) test data and package gas analysis information on the stored soups were obtained. Oxidation data show that the change in flavor from what may be considered acceptable to unacceptable (rating below 5.0) of all vacuum-packed soup products during storage for twelve months at 37°C correlates well with the reduction in oxygen level in the soup package. The relationship was best represented by a first degree polynomial (linear).

Microbiological requirements have previously been established for space foods in terms of total aerobic plate counts, coliforms, fecal coliforms, fecal streptococci, coagulase-positive staphylococci and salmonella on a dry basis. All soup products rehydrated with 65.6°C water at the manufacturer's recommended level of water to solids meet these microbiological requirements.

It is concluded that there is sufficient information to warrant a limited production run and field test of six of the seven soups. The dehydrated soups recommended for this test are spring vegetable, green pea, cream of chicken, onion, chicken noodle, and cream of mushroom.

13. Gould, J.W., Perry, J.T., Jr., Kenyon, E.M. Microwave applications to freeze dehydration. Preliminary evaluation of a 2450 MHz system. 72-24 (FL-146). February 1972 (AD 738149).

A generalized model of microwave freeze-dehydration is presented including the efficiency of power absorption, the mass flow rates of water and water vapor, and the parameters characterizing corona breakdown at the 2450-MHz operating frequency. The effect of chamber pressure, gas composition, size and thickness of the food load, and the operating frequency are discussed theoretically and compared to experimental data for freeze-dehydration at 2450 MHz. The agreement between the theoretical and experimental mass flow rates was good for the majority of the dehydration cycles.

14. Hamdy, M.M. Compression of dehydrated foods; review of literature. Denison Research Foundation, Contract NO. DA 19-129-QM-1630 QMFCI Library Bulletin No. 5. May 1961 (AD 281333).

Nine dehydrated foods, including two freeze-dried products, were compressed and evaluated organoleptically and objectively.

A pilot-scale machine was designed and a production formula was developed.

15. Harris, N., Westcott, D.E., Segars, R.A., and Kapsalis, J.G. Study of the use of a corn flake crumb matrix for corn flake bar, survival type. 72-13 (FL-141). August 1971 (AD 733-947).

The purpose of this study was to determine whether corn flake crumbs could replace part or all of the sugar-coated corn flakes used to product compressed fruit-flavored corn flake bars. (For further information on these products, see military specification MIL-C-35074).

By substituting corn flake crumbs for pulverized sugar-coated corn flakes, considerable savings could be realized. For example, based on purchases of 12 million long range patrol packets by the Armed Forces in FY70, of which one-quarter contain corn flake bars as a component, at least $60,000 could have been saved.

Simple as this sounds, the corn flake crumbs (in bar form) would require comparable storage stability as the pulverized flakes and be able to be compressed to a similar hardness level without brittleness. Test samples were compressed at 2612 pounds per square inch, stored for 9 months at 100°F., and hardness and work measured periodically. In this study, it was found that the Instron Universal Testing Apparatus provided objective textural data on corn flake bars heretofore not obtainable by other methods.

Results indicated that compressed fruit-flavored corn flake bars prepared from corn flake crumbs were as stable from a sensory and textural standpoint as those prepared from pulverized corn flakes. However, on increased compression pressures, the use of corn flake crumbs resulted in bars that were more brittle. Further research must be done to determine if this problem of increased brittleness associated with the use of corn flake crumbs can be overcome.

16. Helmer, R.L. and Tuomy, J.M. Compressed beef jerky. 70-15-FL (FL-98). September 1969 (AD 697746).

A compressed beef jerky bar was developed that has promise for use by the Armed Forces in special stress situations for limited periods of time. The product is prepared by grinding lean beef, adding salt, and smoking it on screen trays until the moisture is in the range of 12 to 15 percent. The product is then compressed in a bar mold using 5,000 pounds per square inch pressure with a 10-second dwell time and packaged in a flexible film pouch. Ratio of compressed to noncompressed product is 1 to 3.

A 6-month storage study at 100°F indicates that the product has excellent storage stability. The water content is sufficiently low to prevent microbiological activity. Preliminary field tests indicate the product performs well for the intended purpose.

17. Helmer, R.L., and Tuomy, J.M. Effect of cooking and fat level on the oxygen uptake of freeze-dried cooked ground beef. 72-54-FL (FL-150). December 1971 (AD 747361).

Ground beef with fat levels of 10, 15, 20, and 25 percent which was cooked in water to 180°F and cooked by boiling for 20 minutes was freeze-dried and stored at 100°F. Products were withdrawn at 2, 4, 8, and 12 weeks, and the head space gas analyzed.

It was found that the more severe cooking resulted in higher oxygen uptakes statistically significant at the 1-percent level. The higher fat levels caused significantly higher uptakes, but they were a small part of the total variance observed.

18. Hewitt, E.J. All-purpose matrix for molded food bars. Evans Research and Development Corporation, Contract No. DA 19-129-AMC-2113. August 1965 (AD 620935).

The object of the program was to produce a suitable matrix for various food components (soups, beverages, and casseroles) which would not detract from the basic flavor of the major food component. A satisfactory matrix was made

from lactose (99%) and sodium carboxymethylcellulose (1%). The matrix can be produced successfully by tray drying or freeze drying. This report summarizes the work performed in Phase I and Phase II of the contract and gives the results of the various shelf-life tests. In general, the lactose/carboxymethylcellulose matrix performed well over the broad range of products that were tested.

19. Hinnergardt, L.C. Storage stability of roasted, thin-sliced, freeze-dried beef. 75-20-FEL (FEL-5). August 1974 (AD 787275).

The semimembranosus muscle was excised from six US Good Grade top rounds. The excised muscles were trimmed into roasts that were 7.6 x 12.7 x 20.3 cm in size. The roasts were stuffed into artificial casings, randomized, and oven-roasted to internal temperatures of 60, 66, or 71°C. The roasts were cooled to 4.4°C and sliced 1.6 mm thick. The slices were frozen at -23°C and freeze-dried with a plate temperature of 52°C and a chamber pressure of 0.3 to 0.5 mm Hg(0.04 to 0.06 KPa) vacuum. The dry material was vacuum-packed and stored at regular intervals (initial 2, 4, 8, 12, and 24 weeks) and evaluated for color, odor, flavor, texture and appearance by a technological taste panel. While high storage temperature and longer storage times had a definite effect on product quality, all samples were considered to be of acceptable quality. The samples with the best texture, flavor, color, and appearance after six months of storage at 28°C were those prepared from roasts cooked to an internal temperature of 60°C.

20. Hinnergardt, L.C. and Sherman, D.E. Evaluation of trial procurement of reversibly compressed freeze-dried foods introduction. 75-96-FEL (FEL-19). October 1974

Six types of reversibly compressed combination food bars were produced by Oregon Freeze-Dry Company. The bars were then stored for one year at 4.4, 21.1, and 38.0°C and evaluated at three-month intervals for organoleptic evaluation, break score, rehydration ratio, and rehydration scores. These bars meet many requirements for patrol type applications when food volume must be reduced to a minimum. However, most of the bars need improved texture and/or rehydration to make them as generally acceptable as Long-Range Patrol type foods.

21. Hollis, F., Jr. Development of moisture binding mimetic agents. General Foods Corporation, Contract No. DARC 17-67-C-0055. 69-50-FL (FL-81). March 1969 (AD 685828).

Moisture mimetic agents and panel techniques have been identified and a bench-top procedure applied to dehydrated compressed food bars to eliminate or reduce the sensation of dryness. Preliminary studies have produced chicken stew, chicken, peas, and cereal bars which have the prerequisite cube form, nutrition, and reduced dryness when consumed. Sensory taste panel data have shown that the classes: polyhydric alcohols, sugars, fruits, fats, and oils exhibit beneficial moisture mimetic properties as additives to

compressed dehydrated foods. Rehydration, storage, and structural stability tests are reported.

22. Parks, T.R., Hsia, S.T., and Sidel, J. Research study to obtain data pertaining to the optimum requirement for dehydration and rehydration of certain freeze-dried fruits and vegetables. Stanford Research Institute, Contract No. DAAC -17-70-C-0187. 73-19-FL (FL-173). February 1973 (AD 758301).

The relative effects of process and raw material variables on final product quality were determined for freeze-dried strawberries, pears, peaches, and apricots, and air-dried lima beans. Raw material variables studied were variety and maturity. Process variables included drying temperature, tray loading, additives, and particle size. Variables involving freezing temperature, chamber pressure, and air velocity were included as applicable. Following drying, samples were packed in a nitrogen atmosphere and placed in accelerated storage (100°F) for 6 months.

Varietal selection, stage of maturity and particle size were significant factors affecting the quality of freeze-dried fruits and air-dried lima beans. Except for strawberries, blanching was found necessary to ensure good appearance and proper rehydration as well as enzyme inactivation in the freeze-drying of pears, apricots, and peaches. Chemical additives did not improve either texture or flavor of rehydrated products.

23. Ishler, N.I. Methods for controlling fragmentation of dried foods during compression. Tronchemics Research, Inc., Contract No. DA 19-129-AMC-2. FD-13. August 1965 (AD 623712).

Methods have been developed whereby a broad range of dehydrated foods can be compressed at 1000 psi into dense, cohesive bars that rehydrate readily with little fragmentation to original characteristics. Examination included 15 food types. Measurement of fragmentation is described. Storage stability is reported. A progress flow diagram is included.

24. Konigsbacher, K.S. 1975. Methods for restoring shape and structure of compressed dehydrated animal and combination products. Foster D. Snell, Contract No. DAAC-17-73-C-0030 75-56-FEL (FEL-10). September 1975 (ADA009734).

The investigation was designed to study the feasibility of using plasticizing agents or other pretreatments to aid in the reversible compression of animal and combination food products.

Results suggest that propylene glycol and glycerol were the two plasticizing agents of choice even though they generally required the addition of a small quantity of steam as a synergist, probably to allow better penetration of the plasticizers to compact the tissues without fragmentation during compression.

During the investigation, several new, apparently technically viable approaches were developed, including a split stream process and a process we called "continuous compression freeze-drying." Neither concept was thoroughly investigated because of time and budget constraints.

The reversibly compressed animal and combination food products were stored under nitrogen in sealed pouches for 90 days at -18°C, 28°C, and 38°C. Aliquots were removed every 30 days and subjected to objective and sensory evaluation. The storage studies of the compressed foods indicated a tendency to progressive deterioration in flavor and color, as well as texture, particularly when stored at 38°C.

The different foods investigated had distinctly different storage characteristics. The products containing chicken seemed to deteriorate most. Compressed shrimp, chili con carne, and diced beef did not deteriorate more than uncompressed, freeze-dried controls. Meatballs showed slight deterioration while the other foods scored between the extremely affected products.

25. LaBelle, R.L. and Acree, T.E. Evaluation of sulfite treatment of red tart cherries, green bell peppers, and apples for dehydration. Cornell University, Contract No. DAAG 17-70-C-0181. 74-14-FL (FL-175). September 1973 (AD 767536).

Red tart cherries, diced green bell peppers, and diced apples were dried in various ways with and without sulfite treatment. Drying alternatives included short exposure to circulating hot air (air-drying), intermediate exposure at reduced temperature and pressure (vacuum-drying), and long exposure to high vacuum in the frozen state (freeze-drying). Sulfite treatment of these materials was accomplished by dipping in an aqueous solution of $NaHSO_3$ (1000-10,000 ppm) or by tumbling in a mixture of SO_2 (2-4%) in air. The dried products were hermetically packaged, in some cases under nitrogen or with desiccant, and stored for six months at -35 or +100°F. Product quality was then evaluated in terms of moisture, residual SO_2, color, odor or flavor, and rehydration characteristics.

The most important consideration in keeping quality was moisture content. In-package desiccation was required to reduce two-stage, air/vacuum-dried cherries or peppers to a moisture level low enough (1-2%) that quality remained acceptable in storage at 100°F. Sulfite treatment and packing under nitrogen were insufficient, separately or together, to provide the necessary protection against browning reactions at higher moisture. And only a slight improvement in quality was noted in sulfited products dried to the lower moisture, in which condition even untreated controls were usually just about acceptable. In-package desiccation was not sufficient to provide final drying for higher moisture products prepared only by air-drying and was mainly unnecessary for those properly freeze-dried.

Air/vacuum-drying, preceded by SO_2 treatment for diced apple or interstage gas-sulfiting for cherries, is recommended. Diced pepper can be prepared like cherries or by freeze-drying, but with sulfiting optional and of less importance.

26. Lampi, R.A. Infiltration of porous foods with high caloric, non-aqueous, edible materials. FMC Corporation, Contract No. DA 19-129-AMC-84. 66-28-FD (FD-45). April 1966 (AD 632311).

Methods together with suitable high caloric formulations were developed for filling the voids of representative baked items and freeze-dried meats, fruits, and vegetables. Panel tests for acceptability and relevant physical, chemical, and microbiological observations are reported for infiltrated products stored for 4 months at a maximum temperature of 38°C. Preparative experience has been extrapolated into an engineering flow diagram for large-scale production of infiltrated foods.

27. Lampi, R.A. The development of built-in mechanism for softening and rehydrating compacted food bars. FMC Corporation, Contract No. DA19-129-AMC-44M. 68-13-FL (FL-66). December 1967 (AD 663827).

Compressed bars representing various vegetables and fruits, a cereal, a bakery item, meat, a casserole-type item, nonfat milk solids, and a high-cook caramel candy were prepared in a manner to accentuate hardness. The effectiveness of various mechanisms for improving bitability and mastication were examined. A laminating technique resulting in a bar of thin layers held together with a mild binder was observed to be generally applicable, since individual layers could be separated for easy mastication and accelerated hydration. For fibrous products bitability was markedly improved by application of the compressive force at 90°C from the direction of the bite. Physical, chemical, and sensory data are recorded for bars stored at four different temperatures.

28. Lampi, R.A., Takahashi, H., Lennon, J., Farrier, R.D., and Egeland, C.A. Studies on the effect of compression on rate of attainment and final equilibrium relative humidity relationships of dehydrated foods. FMC Corp., Contract No. DA 19-129-AMC-11. FD-9. April 1965 (AD 619448).

This report covers the study pertaining to the effects of compression and subsequent storage of eight combination foods on compatibility of components, moisture sorption characteristics, and storage stability. Compression did not produce any differences in equilibrium relative humidity moisture contents. Storage stability as measured by changes in chemical composition and organoleptic acceptability was not significantly affected by compression. Storage relative humidty and time were the major factors in storage stability. The results indicated that the optimum storage relative humidity was 7% or less. Moisture sorption isotherms are included with tabulation of chemical, organoleptic, and rehydration data for all eight food combinations.

29. Lampi, R.A., Takahashi, H., Battey, R.F., Lennon, J., Sierra, S. Ultra-high compression of dried foods. FMC Corp., Contract No. DA19-129-AMC-163. FD-35. November 1965 (AD 626193).

This report covers the study of the effects of pressures as high as 120,000 psi on various dried foods. High compression did not produce any detectable chemical changes. Compressed foods became difficult to rehydrate and exhibited considerable fragmentation when hydrated. Temperature changes occurring during high compression operations were studied. The equipment used for achieving high pressures and the construction of the die are discussed.

30. Luyet, B.J. Investigations on freezing and freeze-drying of selected fruits and vegetables. American Foundation for Biological Research, Contract No. DA 19-129-AMC-81(N). July 1968 (AD 673862).

Investigations were made on the mode of ice crystal formation in fruits and vegetables and the changes produced by freezing and thawing and freeze-drying of the tissues as well as rehydration evaluations.

The diversity of the structure and composition of the fruits and vegetables investigated required the use of different methods of preparation and observation. In general, three methods of exploring the effects of freezing and freeze-drying were used: (1) direct observation of thin sections of fresh tissue under a cryomicroscope during freezing and thawing, (2) observations of material fixed and stained after it had been freeze-dried, and (3) observations of material sectioned while in the frozen state or after freeze-drying.

Observations on the rehydration of thin tissue samples in a specially designed microscope demonstrated the dependence of the rehydration behavior on the structural features of the freeze-dried system.

31. Luyet, B.J. and A.P. MacKenzie. Study of the water binding properties of freeze-dehydrated meat in relation to protein composition and processing treatment. 67-90-FL (FL-57). 1967 (AD 661098).

Accomplishments in this work include: (1) determination of the low- and high-salt-soluble protein fractions, and of the insoluble fraction in beef muscle frozen at 3 rates and freeze-dried at 3 final temperatures; (2) establishment of the adsorption isotherms of the freeze-dried muscle tissues; (3) measurement, by the mechanical pressure method, of the water-holding capacity of the freeze-dried, cooked and noncooked tissues; (4) evaluation of the rate and extent of rehydration of freeze-dried tissues subjected to various pretreatments, and (5) tests of tenderness of meat cooked after being freeze-dried.

32. MacKenzie, A.P. and Luyet, B.J. Recovery of compressed dehydrated foods. American Foundation for Biological Research. Contract No. DAAG17-67-6-0126. 70-16-FL (FL-90). July 1969 (AD 703901).

Seven foods were frozen at various rates, freeze-dried in different ways and adjusted to different moisture contents by exposure to atmospheres of controlled R.H. The resultant materials were compressed, dried, and tested for their capacities to recover initial form and quality on rehydration.

It was observed that processing conditions insuring best recovery can be defined in terms of relative humidity to which a food is exposed prior to compression.

Freeze-dried foods of predetermined moisture content were produced by newly developed processes involving only the sublimation of ice and the direct desorption of a part of the water remaining unfrozen. These methods offered effective alternatives to the method by which fully freeze-dried materials are moistened by resorption prior to compression.

Compression in vacuum was successfully demonstrated. Similarly, freeze-drying adjustment of the water content, compression, and final drying were realized in a single apparatus. These methods were each shown to possess special advantages.

Additional experiments were conducted on the compression of solvent-extracted foods. Freeze-dried, compressed, and restored foods were also examined by light and electron microscopic techniques. From these additional studies, some indications were obtained of the mechanisms and factors contributing to restoration.

33. MacKenzie, A.P. and Luyet, B.J. Recovery of compressed dehydrated foods. Phase II. American Foundation for Biological Research, Contract No. DAAG 17-67-C-0126. 72-33-FL (FL-148). December 1971 (AD 737315).

Twelve foods, alone and in combination, were frozen at various rates, freeze-dried in different ways and brought to certain predetermined water contents by exposure, via the vapor phase, to water at controlled activities (a_w's). The moist freeze-dried materials were subjected to compression and to further drying, after which they were rehydrated.

It was found that processing conditions insuring best recoveries could be defined in terms of water activities to which foods were adjusted prior to compression; that is, the conclusion drawn on the basis of the Phase I studies was confirmed and extended. It was, moreover, shown that composite foods were more likely to respond well to compression where component items were selected on the basis of compatible a_w-dependent behavior.

The times taken by foods freeze-dried by conventional methods to reach constant water contents by contact with atmospheres of intermediate a_w were found not to exceed several hours. Moistening via the vapor phase proved to possess special advantages where foods destined for compression were freeze-dried in admixture.

Freeze-drying by sublimation and direct desorption of remaining water to various predetermined water activities was subjected to further analysis. Pilot-scale apparatus was designed, constructed, tested, and operated successfully.

Supplementary studies were completed in continued attempts to define factors responsible for recovery. Whole and solvent-extracted foods were examined by light and scanning electron microscopic techniques. Indications of the nature of certain irreversible changes resulting from compression were obtained.

34. Mone, P.E. and Mink, L.D. Requirements for instant prepared, ready-to-eat, freeze-dried scrambled egg. Swift and Co., Contract No. DA 19-129-AMC-121. 67-49-FD (FD-54). January 1967 (AD 650637).

In the design of "Quick Serve Meals" as a military operational ration, there was a need for a quickly prepared egg product in the breakfast menus. A prototype scrambled, cooked, freeze-dried whole egg product was developed which possessed the appearance, aroma, flavor and texture similar to pan-fried scrambled egg, after rehydrating in hot water for 1 to 3 minutes. More complete information covering raw material and processing procedures was needed in order to produce a satisfactory product on a plant scale. The work covered in this report was carried out to investigate the raw material, processing methods and equipment necessary for the efficient production of freeze-dried scrambled eggs.

Summer and winter produced USDA table grades A and B shell eggs were obtained from 6 different geographical areas of the United States to provide for a random selection of eggs from major egg producing areas. In addition, table grade frozen egg prepared from table grade shell eggs was included in the study. The eggs were produced from predominately White Leghorn flocks. All eggs after receipt were held at 40°F until processed except that the frozen table grade egg was held at -10°F. The eggs were weighed, check graded, broken, homogenized, pasteurized, stabilized (desugared), precooked, frozen, freeze-dried, and vacuum-and nitrogen-treated before sealing in both cans and pouches. The packaged freeze-dried eggs were stored at 38°-40°F and 100°F for six months. They were evaluated organoleptically for quality by a trained panel initially and at the end of the storage period. Bacteriological and chemical data was obtained on the raw and processed eggs.

Geographical source of the eggs had no effect on the quality of the end product. There were no significant differences in the organoleptic criteria of the finished product produced from grade A or grade B table grade shell eggs. Finished product produced from grade B frozen eggs was significantly poorer in organoleptic properties than from grades A and B eggs. Freeze-dried scrambled egg packed in cans kept better in storage than when packed in pouches. Oxygen level in headspace gas did not appear to affect flavor stability. Overcooking in the scrambling process and rehydration procedure had a deleterious effect on quality. Increasing the levels of enzyme preparation and hydrogen peroxide and raising the incubation temperature to 105°-112°F reduced the desugaring time to 2 hours.

Detailed recommendations are provided for raw material, plant equipment, and processing procedure.

35. Morris, E.R. Objective Tests for use in the technology of compressed foods. Midwest Research Institute, Contract No. DA 19-129-AMC-130. FD-26. September 1965 (AD 624869).

Objective methods are described for determining specific physical, chemical and microbiological properties of compressed food bars. The suitability of these methods was demonstrated by application to fresh and aged (3 months at 100°F) bars prepared from meat, fruit, cereals, vegetables, and dairy products and which represented broad concentration ranges of moisture, fat, protein, carbohydrate, and common approved chemical additives.

36. Newlin, H.E. and Morris, E.R. Development of food bars employing edible structural agents. Midwest Research Institute, Contract NO. DA 19-129-QM-1987. FD-20. August 1965 (AD 620884).

Several pastes and a hot melt prepared from edible components were found effective binders for preparation of bars from any combination of dry foods. Effectiveness of these edible binders was demonstrated on bars prepared from different types and compositions of food. Bars remained acceptable after storage for three months at 100°F and retained adequate resistance to impact and shear.

37. Pavey, R.L. Fabrication of food bars based on compression and molding matrices. Swift and Co., Contract No. DAAG 17-67-C-0068. 69-69-FL (FL-88). February 1969 (AD 688720).

Dried foods, plasticized to prevent fragmentation, were compressed with appropriate binders into bars of approximately equal size, density, and caloric content (140 $\pm$ 14 kcal/bar). Bars representing the following food items were designed, formulated, fabricated and evaluated for physical,

chemical, and sensory characteristics after storage for 3 months at 38°C: (1) beef stew, (2) chicken and rice, (3) barbecue pork, (4) chili with beans, (5) shrimp creole, (6) chicken a la king, (7) tuna salad, (8) scrambled eggs with bacon, (9) mixed creamed vegetables and (10) apple pie filling. Complete information on all formulations and processing is supplied.

In accordance with design requirements, bars were rated by a taste panel as acceptable for consumption from the dry-compressed state and for consumption after rehydration for 20 minutes in water at 80°C (25°C for items consumed at room temperature). Bars were evaluated for cohesiveness, dimensional stability under pressure, ease of shear by the incisors and subsequent mastication. Observations on free fatty acids, peroxide value, and browning (reflectance units) are recorded for each bar at the time of fabrication and after the referenced storage.

38. Pavey, R.L. Fabrication of food bars based on compression and molding matrices. Swift and Co. Contract No. DAAG 17-67-C-0068. 60-67-FL (FL-111). June 1970 (AD 717289).

Dried foods, some plasticized to prevent fragmentation, were compressed with appropriate binders into bars of approximately equal size, density and caloric content (148 ± 25 kcal/bar). Bars representing the following food items were designed, formulated, fabricated and evaluated for physical, chemical and sensory characteristics after storage for 3 months at 38°C: (1)Citrus Fruit Drink, (2) Hot Chocolate Beverage, (3) Cream of Mushroom Soup, (4) German Potato Salad, (5) Cole Slaw, (6) Pineapple-Cottage Cheese Salad (7) Welsh Rarebit, (8) Crab Meat Cocktail, (9) Chocolate Pudding, and (10) Pineapple Fruit Pudding. Complete information on all formulations and processing is supplied.

In accordance with design requirements, bars were rated by a taste panel as acceptable for consumption from the dry-compressed state and for consumption after rehydration for 20 minutes in water at 70°C (25°C for items consumed at room temperature). Bars were evaluated for cohesiveness, dimensional stability under pressure, ease of shear by the incisors and subsequent mastication. Observations on free fatty acids, peroxide value and browning (fluorescence units) are recorded for each bar at the time of fabrication and after the referenced storage.

39. Pavey, R.L. Study Techniques for controlling flavor intensity in compressed foods. Swift and Co., Contract No. DAAG 17-67-C-1021. 75-49-FEL (FEL-6). 1975 (ADA 006031).

Commercially available encapsulated flavorings were evaluated in compressed food bars representing high salt, high pepper, high onion, high tomato, high acid and high sugar products in an attempt to control these flavor intensities when consumed in the dry form and after rehydration. Two of the six products evaluated - chili with beans and barbecued pork - were

found acceptable in regard to flavor intensity through the use of hydrogenated vegetable shortening in the formulation. The remaining four products had flavor intensity differences of a magnitude in excess of that necessary to be called of equal intensity in one or more flavor characteristics which were not possible to overcome with use of commercially available encapsulated flavors. Special encapsulation procedures will be pursued in Phase II of this effort in attempts to control these flavor intensities.

40. Peltre, P.R.F. Freeze-dehydration by microwave energy. 75-84-FEL (FEL-16). December 1974 (ADA 009578).

A general unsteady state analysis is used to derive a mathematical model of the freeze-drying process using microwave heating. The system of partial differential equations is solved numerically by Crank-Nicolson method. The temperature and water vapor concentration profiles inside the material being dried are calculated.

The model is applied to simulate the freeze-dehydration of beef meat by microwave dielectric heating at 2450 MHz. The results of the calculations show that the microwave freeze-drying process is mainly controlled by heat transfer. The study of the effects of the process constraints and variables upon the drying time and/or the freeze-dryer output indicates that an optimal operation (highest product yield) would be for an operation near corona and overheating (or melting) conditions. Drying times as short as 1-1/2 hours should be possible, if corona is to occur beyond a peak strength of 255 V/cm.

Experimental drying curves have been obtained for the freeze-drying of beef meat with microwave heating at 2450 MHz. The experimental drying curves are in good agreement with those simulated by the model. The small differences may be attributed to an uncertainty in the numerical values used for the physical properties in the model or non-ideal experimental conditions. An experimental value of the heat transfer coefficient of 1.9×10^{-4} cal/sec/cm^2/°C (at the surface of the sample exposed to the vacuum) is also obtained.

41. Pilsworth, M.N., Jr. and Hoge, H.J. The compression of freeze-dried beef to form bars; plasticizing with water tranferred as a vapor. 73-56-PR. June 1973 (AD 766709).

The plasticizing of freeze-dried beef by water addition and the compression of the beef to form rehydratable bars have been accomplished using two different sets of equipment. Water addition has been accomplished by transfer of water vapor to the meat in an evacuated system. The water added should be about 12% of the weight of the dry meat. It can be transferred to a period of 3 to 5 hours. Fat weakens the bars and when

high-fat beef is used, it may be desirable to use a binder to give the bars sufficient mechanical strength. A forming pressure of 3000 psi is suitable for some lots of beef. High forming pressures should be avoided since they generally give bars that reconstitute (rehydrate) poorly.

Some useful basic information is given on adsorption and desorption, on the temperatures reached as these processes occur rapidly, and on the vapor pressure and heat of vaporization of the ice and associated volatile constituents of freeze-dried raw beef.

42. Pilsworth, M.N., Jr., Segars, R.A., and Hoge, H.G. An experimental study of the freeze-drying of raw beef. 73-12-PR. October 1972 (AD 769592).

Freeze-drying curves for small sticks of beef are presented, and it was found that in many cases, the specimen weight was accurately represented by a quadratic function of the time. In many runs, the drying was interrupted and the cross-section of the ice core was measured, after which freeze-drying was completed. A graph showing ice-core diameter versus percent of water (including ice) remaining in the specimen is given, showing that the ice core does not disappear until the water content has been reduced to about 1% of the original weight (about 4% of the dry weight). It is, therefore, impractical to stop the freeze-drying process at a higher water content in order to permit compression without crumbling. The required moisture could be left in the meat, but it will not be uniformly distributed; the wet core will affect product quality adversely.

43. Rahman, A.R., Gorfein, H., Westcott, D.E., Schafer, G., and DuBose, D. Effect of storage conditions on the quality of compressed food bars. 75-64-FEL (FEL-28). 1975 (ADA 006494).

Four prototype compressed bars - cherry, beef noodle soup, corn flake, and bean salad - were developed in the laboratory. They were then produced by commercial firms and were evaluated in prototype individual ration packets in the field. Storage studies indicate that the average technological ratings for color, flavor, and texture of dry as well as rehydrated bars were not adversely affected after storage for 3, 6, and 12 months at 4, 21, or 38°C or for 18 months at 4 or 21°C. The ratings of beef noodle soup were somewhat lower than the rest of the bars throughout the storage tests.

44. Rahman, A.R., Miller, K., Schafer, G. Factors affecting the quality of freeze-dried peas. 70-8-FL (FL-94). August 1969 (AD 692301).

The effects of extended blanching, sulfiting and packaging on the quality of freeze-dried peas prepared from commercially frozen products and stored

for six months at 100°F were investigated. Results indicated that acceptable freeze-dried peas can be prepared from commercial individually quick-frozen (IQF) peas by thawing, slitting, sulfiting, refreezing, freeze-drying and packaging in tin cans under vacuum or nitrogen.

45. Rahman, A.R., Schafer, G., Prell, P., and Westcott, D.E. Nonreversible compression of intermediate moisture fruit bars. 71-60-FL (FL-137). July 1971 (AD 728820).

Edible, compressed fruit bars were successfully developed by reducing the moisture content of the fruit ingredients such as dates, figs, maraschino cherries, and others to approximately 8 percent (a range of 7 to 14 percent is applicable) and the incorporation of approximately 2 percent lecithin to enchance the texture. The bars were stable during storage for 6 months at 100°F. The 4 test bars were also stable during storage for 12 months at 70°F.

46. Rahman, A.R., Schafer, G., Taylor, G.R., Westcott, D.E. Studies on reversible compression of dehydrated vegetables. 70-36-FL (FL-102). November 1969 (AD 698457).

Compressed bars approximately 3 x 1 x 1/2 inches have been developed from freeze-dried peas, corn, spinach, carrots, green beans, as well as air-dried sliced onions. Rehydration ratio and texture as measured by shear press were not significantly affected by compression. Compression ratios obtained were: peas 1:4, corn 1:4, sliced onions 1:5, spinach 1:11, carrots 1:14, and green beans 1:16.

47. Rahman, A.R., Schmidt, T.R., Criz, D.S., Johnson, K.R. and Anderson, E.A. Non-caking freeze-dried applesauce. 74-37-FL (FL-190). March 1974 (AD 779456).

A study was initiated to develop an applesauce which resists caking when subjected to elevated temperatures such as 37.7°C for 2 weeks and/or 57°C for 3 hours as required by NASA. Juice was extracted from McIntosh apples at different levels ranging between 15.8 and 77.0 percent by weight. The following results were obtained: (1) the degree of caking of the freeze-dried applesauce powder was correlated with the amount of juice extracted, (2) correlations were established between the percentage of juice extracted and each of the following: bulk density, soluble solids, and reducing sugars of the applesauce powder, (3) reducing sugars appear to be the factor contributing most significantly to the caking with the higher reducing sugar levels producing the higher degrees of caking, and (4) flavor and texture of the rehydrated applesauce powders were adversely affected by higher juice extractions.

48. Rahman, A.R., Taylor, G.R., Miller, K., and Johnson, K.R. Factors affecting the quality of freeze-dried corn. 70-17-FL (FL-96). September 1969 (AD 693774).

The effect of extended blanching, sulfiting, and packaging on the quality of freeze-dried corn prepared from commercially-frozen products and stored for six months at 100°F and 12 months at 70°F were investigated. Results indicated that acceptable freeze-dried corn can be prepared from commercial individually-quick-frozen (IQF) corn by freeze-drying without any further treatments and packaged in tin cans under vacuum or nitrogen.

49. Rahman, A.R., Taylor, G.R., Miller, K., and Johnson, K.R. Factors affecting the quality of freeze-dried green beans. 70-20-FL (FL-97). September 1969 (AD 694354).

The effect of extended blanching, sulfiting, and packaging on the quality of freeze-dried green beans prepared from commercially frozen products and stored for six months at 100°F were investigated. Results indicated that acceptable freeze-dried green beans can be prepared from commercial frozen green beans by freeze-drying without any further treatments and packaging in tin cans under vacuum or nitrogen.

50. Rahman, A.R., Taylor, G.R., Schafer, G., and Westcott, D.E. Studies of reversible compression of freeze-dried RTP cherries and blueberries. 70-52-FL (FL-105). February 1970 (AD 704340).

Compressed discs, approximately 3-5/8 inch in diameter to fit No. 2-1/2 cans, of freeze-dried blueberries and red tart pitted (RTP) cherries have been produced. Technological evaluations of pies prepared from cherries and blueberries compressed at 100 to 1500 pounds per square inch, indicate no significant difference in flavor, texture, and appearance from those prepared from the uncompressed counterpart. Compression ratios obtained for freeze-dried blueberries and cherries, respectively, were 1:7 and 1:8. Compression ratios were 1:13 and 1:12, respectively, when compared to loose frozen product.

51. Ranadive, A.S., Huang, E.A., and Seltzer, E. Investigation of rehydration characteristics of compressed comminuted meats. Rutgers University. Contract No. DAAG 17-73-C-0015. 74-53 (FEL-33). June 1974 (ADA 009104).

This report presents formulations of dehydrated compressed comminuted meat products with controlled rehydration properties.

Meatballs and pork sausages are deep-fat fried, freeze-dried, slightly remoistened, compressed into blocks and then redried. Selection of suitable binder systems is vital for insuring adequate rehydration without over-imbibition.

Combinations of certain cross-linked and/or pregelatinized modified starches with small amounts of isolated wheat gluten were found to impart desired characteristics.

52. Roth, N., Wheaton, R., and Cope, P. Effect of exposure to oxygen on changes in meats and vegetables during storage. Whirlpool Corp., Contract No. DA 19-129-AMC-116. FD-31. November 1965 (AD 625484).

Reported are the procedures and results of a six-months storage stability study conducted with precooked beef, chicken, carrots, and spinach which had been freeze-dried to 2 and 4% residual moisture levels and stored under 2, 4, and 20% oxygen atmosphere at 100°F. Exposure to oxygen was the primary cause of product deterioration. The effect of residual moisture level and length of storage on quality attributes was product dependent.

53. Salunkhe, D.K., Do, J.Y., and Srisangnam, C. Investigations of factors to improve texture and color of freeze-dehydrated and subsequently compressed red tart pitted cherries. Utah State University. Contract No. DAAG 17-72-C-0187. 74-51-FL (FL-196). June 1974 (AD 78339).

Freeze-dehydrated and compressed red tart pitted cherries, cultivar Montmorency, were stored at 21°C and 38°C for 12 and 6 months. Quality evaluations on color, firmness, acidity, alcohol extractable color substances, and ascorbic acid showed a greater degradation of overall quality at 38°C than 21°C as storage time was increased. Sensory evaluations were made on rehydrated cherries prepared as pies. Sulfited cherries retained better color but the high temperature (38°C) seemed to offset the sulfiting effects. Calcium chloride treatment showed some firming effects. Lesser compression pressure (690 KPa) gave better texture after rehydration. Red food color incorporation to the freeze dehydrated RTP cherries improved the color; however, this was not successful on samples that had turned brown after storage at 38°C.

54. Sharma, S.C. and Seltzer, E. Procedures to minimize mechanical damage to freeze-dried foods. Rutgers University, Contract No. DAAK-03-73-C-0013. 76-22-FEL (FEL-20). March 1976 (ADA 02905).

The objective of the studies reported herein was to develop procedures principally to minimize mechanical breakage during handling and transport, while retaining or improving other quality characteristics of ten meat/seafood products. The effects of freezing rate prior to freeze-

drying, dehydration parameters, and various food grade additives were evaluated. Formulations have been developed which result in the products which are mechanically stable and exhibit superior texture, rehydration, and organoleptic qualities. After being stored at 38°C, the products with newly developed formulations exhibited a favorable retention of all these qualities as well as a lower extent of rancidity and color change. The major advance discovered in this study has been the effectiveness of using salt soluble meat proteins, dispersed by an optional incorporation of phosphates, as binders for the meat tissues, in a process sequence which includes lyophilization. The phosphate treatment is part of the additive system, the effectiveness of which is augmented by sodium chloride and in some cases by wheat gluten and meat emulsion. Thereby, the major objective of minimizing mechanical damage appears to have been achieved along with the improvement in the various collateral quality factors.

55. Tuomy, J.M. Development of reversibly compressed freeze-dried foods for use in individual ration packets. 72-4-FL (FL-135). June 1971 (AD 731483).

Six combination meat prototype reversibly compressed bars were developed that are considered candidates for use in individual ration packets. In addition, four bars were developed in the plant products area representing the areas of soups, salads, fruits, and breakfast foods.

56. Tuomy, J.M. and Hinnergardt, L.C. Effect of headspace oxygen on the quality of freeze-dried raw beef patties. 69-54-FL (FL-87). November 1968 (AD 681883).

Freeze-dried raw beef patties were packed in cans with vacuums ranging from 30 to 0 inches and stored at 100°F. Cans were withdrawn from storage at intervals for 24 weeks and evaluated by a technological panel for flavor, odor, and texture. In addition, the headspace gas was analyzed for oxygen by chromatographic means and the rehydration ratio determined.

The oxygen uptake by the product correlated at the 1-percent level with flavor, odor, texture, and rehydration ratio of the product. Storage at 100°F was found to have more of an adverse effect on the organoleptic properties of the raw beef patties than it did with cooked combination items such as chili con carne, although the amount of oxygen originally present in the headspace [illegible] had a significant effect. Both storage and oxygen had a significant effect on the rehydration ratio of the beef patty, whereas they did not with the cooked combination items as determined in other studies.

57. Tuomy, J.M. and Hinnergardt, L.C. Effect of moisture on the quality of freeze-dried spaghetti with meat sauce. 71-26-FL (FL-122). December 1970 (AD 719176).

Freeze-dried spaghetti with meat sauce, used as one of the main components in the Food Packet, Long Range Patrol, was packed with vacuums ranging from 0 to 29 inches and moistures ranging from about 1 to about 5.5 percent. The samples were stored for 24 weeks at 100°F with withdrawals at 0, 3, 6, 12, and 24 weeks. The products were evaluated by a 10-member technological panel at each withdrawal. Oxygen uptake and carbon dioxide production were determined.

Analysis of variance and regression analysis showed that the moisture level had a significant effect on the panel response and oxygen uptake but contributed only a small part of the variance observed. Increased moisture tended to cause an increase in CO_2 production.

58. Tuomy, J.M., Hinnergardt, L.C., and Helmer, R.L. Effect of headspace oxygen on the quality of freeze-dried beef and chicken stew. 68-65-FL (FL-78). May 1968 (AD 617628).

To study the effect of headspace oxygen on quality, beef, and chicken stews freeze-dried after formulation were packed in cans with vacuums ranging from 30 to 0 inches. The cans were stored at 100°F and tested at intervals by a technological taste panel for 24 weeks. In addition, the headspace gas in each can was analyzed by chromatographic means for oxygen and carbon dioxide and the rehydration ratio determined at each interval.

Almost all of the oxygen available to the product was taken up during the 24-week period although at a slightly slower rate by the chicken stew than by the beef stew. Panel ratings for flavor and odor corresponded to the quantity of oxygen absorbed by the product with lower ratings being obtained with the higher oxygen uptake figures. No correlation was found between the rehydration ratio and oxygen uptake.

The results emphasize the importance of limiting headspace oxygen in military specifications for freeze-dried products. The beef and chicken stews may not absorb oxygen as rapidly and thus not deteriorate as rapidly as some freeze-dried products, but in time will absorb enough oxygen, if it is available, to become unacceptable.

59. Tuomy, J.M., Hinnergardt, L.C. and Helmer, R.L. Response of cooked freeze-dried combination meat items to oxygen. 70-64-FL (FL-110). May 1970 (AD 707921).

Eight freeze-dried combination meat items used as main components in the Food Packet, Long Range Patrol were packed with different amounts of oxygen in the headspace gas and stored at 100°, 70°, 40°F with withdrawals

at 0, 2, 4, 12, and 24 weeks. The eight items were beef hash, beef stew, beef with rice, chicken and rice, chicken stew, chili con carne, pork with potatoes, and spaghetti with meat sauce. Oxygen uptake was determined. With the product stored at 100°F, the product was also evaluated by a 10-member technological panel and the rehydration ratio determined.

Regression analysis showed that flavor and odor correlated highly with oxygen uptake and the slopes of the regression lines were almost identical for the eight items. No correlation was found between rehydration ratio and oxygen uptake. Analysis of variance indicated that vacuum, temperature, and time had significant effects of oxygen uptake, but the relative importance of temperature and time was different for different products. Multiple linear regression equations were derived using oxygen available, temperature, and time as independent variables and oxygen uptake as the dependent variable. The multiple correlation coefficients ranged between 0.61 and 0.79. Highly significant linear correlation coefficients were found with the regression of time on log mol fraction of oxygen remaining. This indicates that the oxygen uptake reactions have attributes of a first order reaction.

60. Tuomy, J.M., Lechnir, R.J., Miller, T. Effect of predehydration variables on the quality of feeze-dried cooked sliced beef. QMFCIAF Report No. 27-61. December 1961 (AD 277937).

The effect of meat grade, state (fresh or frozen), method of cooking (steam or water) degree of cook, and speed of freezing (for dehydration) on tenderness of freeze-dehydrated cooked sliced beef was investigated. It was found that tenderness was mainly dependent upon the degree of cook among the variables tested, and the degree of cook necessary to produce consistent tenderness is in excess of that usually considered normal in plant practice except for such products as T.V. dinners. Shear press reading correlated quite closely with panel results under the conditions of this investigation.

61. Tuomy, J.M., Lechnir, R.J., and Miller, T. Effect of dehydration variables on the quality of freeze-dried, cooked, sliced beef. QMFCIAF Report No. 14-62. June 1962.

This report gives the results of a factorial experiment on effects of dehydration variables on quality of freeze-dried, cooked, sliced beef. Variables studied were platen temperature, dehydration pressure, prefreezing versus evaporative freezing, and overdrying. Platen temperature and overdrying had no significant effect on tenderness, cutability, or juiciness of product. Evaporative freezing and higher drying pressures adversely affected the product.

62. Tuomy, J.M., Lechnir, R.J., and Miller, T. Effect of temperature on the tenderness of cooked beef. QMFCIAF Report No. 28-62. August 1962 (AD 282973).

This report shows that degree of tenderness of beef attained through cooking is dependent upon inherent tenderness of the meat, time, and temperature. Initial effect of heat is toughening due to protein coagulation progressively occurring as temperature increases. Tenderization of coagulated protein is a function of temperature and time with little or no tenderization taking place below 180°F. There was no evidence in this study that connective tissue played any part in toughness of the meat although this probably would not hold true for different cuts. Kramer shear press results correlated highly with panel results for tenderness and cuttability. The work is part of a larger study on organoleptic properties of freeze-dried meats and how to measure them objectively.

63. Tuomy, J.M., Ogden, L.V., and Helmer, R.L. Effect of processing conditions on cooked, freeze-dried spaghetti with meat sauce. 69-55-FL (FL-85). January 1969 (AD 681884).

The effects of refrigerated holding before freezing, time in freezer before freeze-drying, dryer platen temperature, dryer pressure, and storage at 100°F on the flavor, odor, texture, and color of cooked, freeze-dried spaghetti with meat sauce were studied. All of the variables significantly affected the organoleptic properties of the dried product. Several significant statistical interactions were found.

The interaction storage in freezer x dryer pressure was significant at the 1 percent level with the highest organoleptic ratings being obtained for zero freezer time and lowest pressure, and the lowest ratings at zero freezer storage and highest pressure. This interaction should be studied further.

Oxygen uptake analysis during storage of the product at 100°F showed statistically significant effects caused by dryer pressure and platen temperature and their interactions. This is another area requiring further study.

64. Tuomy, J.M., Shafer, H.W., and Hinnergardt, L.C. Effect of freeze-drying conditions on the quality of spaghetti with meat sauce. 71-35-FL (FL-126). March 1971 (AD 721289).

The effects of freeze-drying pressure, platen temperature, storage temperature, and storage time on appearance of product out of the dryer, rehydration ratio, and oxygen uptake of freeze-dried spaghetti with meat sauce were studied.

It was found that high dryer pressure (1.5-2.5 mm of mercury) appeared to cause vacuum-drying and that high platen temperatures (175-200°F) caused browning. Low pressure (0.5 mm of mercury) resulted in the best rehydration ratio, whereas low and high plate temperatures gave the best rehydration. While platen temperature and dryer pressure had statistically significant effects on oxygen uptake, their contribution to the total variance observed was small.

65. Tuomy, J.M., Stentz, R.L., and Helmer, R.L. Effect of processing conditions in the quality of cooked, sliced, freeze-dried beef. 68-53-FL (FL-70). April 1968 (AD 669618).

The effects of temperature reached in cooking, freezer age before drying, platen temperature, dryer pressure, and time of storage at 100°F on the flavor, odor, and texture of cooked, sliced, freeze-dried beef were studied. All of the variables significantly affected the organoleptic properties of the dried beef and the overall effect of freeze-drying was a decrease in acceptability. Several significant statistical interactions were found but, in general, their direction was the same as found for the main effects.

Higher cooking temperature and dryer pressure within the ranges studied were found to result in higher organoleptic ratings. Freezer age before drying adversely affected the ratings. Differences in platen temperature resulted in almost no effect between 100 and 150°F, but in a significant decrease in ratings from 150 to 200°F. As expected, time of storage at 100°F resulted in decreased ratings. Significant statistical interactions were found between storage X dehydrator pressure and storage X dehydrator temperature. The interaction of storage X cooking temperature was not significiant.

This study emphasizes the fact that processing conditions for a product such as cooked, sliced, freeze-dried beef must be carefully controlled to maintain product quality.

66. Tuomy, J.M., and Young, R.G. Adaptability of shear presses to specifying tenderness of cooked, sliced, freeze-dried beef. AMXFC Report No. 39-62. 'ecember 1962 (AD 293159).

A series of runs was made in which the tenderness and cuttability of cooked sliced beef, rated by a trained technological panel, were compared to the ratings obtained with the Warner-Bratzler and the Kramer shear presses. The correlations found between the various ratings were good, and it is believed that the shear press reading can be developed into requirements for freeze-dried meats which would increase assurance of procuring

satisfactory end-products. Differences of product slice thickness from 1/8 to 1/4" were found not to make an appreciable difference in the final ratings by either the panel or the presses provided that the slices could be combined to give the same height stack for the shear press.

67. Wells, F.E. Evaluation of freeze-dried chicken: effects of cooking and deboning methods on costs and quality. Midwest Research Institute, Contract No. DA 19-129-AMC-116 FD-10. May 1965 (AD 619280).

Effects of three deboning techniques with three classes of poultry were studied. Evaluations were based upon cost of production, contamination by bacteria, and organoleptic tests for quality of the dried meat.

The results indicate there is reason to recommend a deboning procedure where carcasses are fully cooked before deboning. Fowl appear to give better meat yields than fryers or roasters.

A method for bacteriological examination is described. Cautions concerning sanitation in relation to deboning methods are noted.

Other Publications

1. Anonymous. 1942. Compression of dehydrated foods. Massachusetts Institute of Technology, Report No. 1.

2. Anonymous. 1943. How to compress foods. Food Ind. 15:64-65, 130.

3. Anonymous. 1943. Compression of dehydrated foods. Massachusetts Institute of Technology, Report No. 2.

4. Anonymous. 1943. Compression of dehydrated foods will save shipping space. Food Ind. 15:74.

5. Anonymous. 1944. Food compression research. U.S. Agr. Res. Admin. Final Report. PB 37991.

6. Anonymous. 1944. Huge rotary press at doughboy mills. Food Packer n. 39 - July.

7. Anonymous. 1945. Field service on vegetable and fruit compression installations; study of equipment and problems in commercial compression of dehydrated foods. U.S. Agr. Res. Admin Report. PB 8148.

8. Anonymous. 1948. Experimental compression of dehydrated foods. U.S.D.A. Miscellaneous Publication 647.

9. Bennet, R.G., Wisakowsky, E.E., Barns, E.E., and Rahman, A.R. 1977. Effect of maturation on the quality of freeze-dried compressed product. Proceedings - Institute of Food Technologists, Annual Meeting, Philadelphia.

10. Berlin, K., Kliman, P.G., and Pallansch, M.J. 1966. Surface areas and densities of freeze-dried foods. Ag. Food Chem. 14(1):15-17.

11. Brockmann, M.C. 1966. Compression of foods. R&D Associates Activities Report. 18(2): 173-177. US Army Natick Labs, Natick, MA.

12. Brockmann, M.C. 1970. Minimizing weight and bulk. Proceedings, symposium on feeding the military man. R&D Associates. US Army Natick Laboratories, Natick, Mass.

13. Brockmann, M.C. 1974. Freeze-drying. In "Encylcopedia of Food Technology," Ed. Johnson, A.H. and Peterson, M.S. AVI Publishing Co., Inc. Westport, CT.

14. Carn, R.M. 1972. Limited freeze-drying. M.S. Thesis in Chemical Engineering, U. of California-Berkley.

15. Clowes, R.E., Ross, I.J., and White, G.M. 1973. Properties of compressible granular materials as related to forces in bulk storage structures. Trans. of ASAE 16(3): 478.

16. Curry, J.C. 1974. Rehydration characteristics of compressed freeze-dried carrot tissue. Ph.D. dissertation, Texas A&M University, College Station, Texas.

17. Dalgleish, J.M. 1953. Mechanisation of meat block production. Unclassified Report SA/DA/RM/54. Ministry of Agric. Fisheries, and Food. Great Britain.

18. Dibbern. 1976. Food technology of military significance-foreign (U). Paper No. 5 fabricated food bars. US Army Material Development and Readiness Command Foreign Science and Technology Center. DST-1840R-487-76. 41p.

19. Do, J.Y., Srisangnam, C., Salunkhe, D.K., and Rahman, A.R. 1975. Freeze dehydrated and compressed sour cherries. I. Production and general quality evaluation. J. Food Technol. 10: 191-201.

20. Do, J.Y., Potewiratananond, S., Salunkhe, F.K., and Rahman, A.R. 1976. Freeze dehydrated compressed sour cherries. II. Stability of anthocyanins during storage. J. Food Technol. Vol. 11.

21. Dunlop, W.C., Jr. 1946. Vacuum-drying of compressed vegetable blocks. Ind. Eng. Chem. 38: 1250-1253.

22. Emani, S.H., Flink, J.M., and Rahman, A.R. 1977. Simultaneous compression and freeze-drying of foods. Annual Meeting, Institute of Food Technologists, Philadelphia.

23. Fairbrother, J.G. 1967. Organoleptic evaluation of foodstuff for service use. Army Food Science Establishment Report Number MR/27. Scottsdale, Tasmania.

24. Fairbrother, J.G. 1968. Compressed formulated products - A new concept in dehydrated foods. Food Technol. 22:100-102.

25. Fairbrother, J.G. 1968. The compression of formulated dessert-type dried foods. Army Food Science Establishment, Report Number MR/32. Scottsdale, Tasmania.

26. Fairbrother, J.G. and Smith, S.W.C. 1968. Compressed dehydrated foods. Report No. 1/68, Australian Military Forces, Food Research Station, Scottsdale, Tasmania.

27. Ferrel, R.E., Pence, J.W., Olson, R.L., and Taylor, E.C. 1962. Foods for fallout shelters: IV. A special shelter ration based on a cereal wafer. Food Technol. 16:45-49.

28. Flink, J.M. 1977. A simplified cost comparison of a freeze-dried food with its canned and frozen counterparts. Food Technol. 31:50-56.

29. Gillies, M.T. 1974. "Compressed food bars." Noyes Data Corp. Park Ridge, New Jersey.

30. Gooding, E.G.B. 1952. Meat and vegetable blocks. Unclassified Report SA/DA/RM/31. Ministry of Agriculture Fisheries and Food. Great Britain.

31. Gooding, E.G.B. 1955. Problems of cabbage dehydration. Food Manuf. 30: 311.

32. Gooding, E.G.B. and Duckworth, R.B. 1958. The effect of in-package desiccation on the storage properties of compressed and uncompressed dehydrated cabbage. J. Sci. Food Agric. 9:14-18.

33. Gooding, E.G.B., Duckworth, R.B., MacDougall, D.G., and Casey, J. 1958. The storage life of dehydrated vegetables III. Unclassified Report SA/DA/RM/82, Ministry of Agriculture Fisheries and Food, Great Britain.

34. Gooding, E.G.B. and Rolfe, E.J. 1957. Some recent work on dehydration in the United Kingdom. Food Technol. 11: 302-306.

35. Gooding, E.G.B. 1962. The storage behavior of dehydrated foods. Recent Advances in Food Science 2:23-38.

36. Hay, J.M. 1958. The compression of dehydrated cabbage. Unclassified Report SA/DA/RM/90, Ministry of Agriculture, Fisheries and Food. Great Britain.

37. Hendel, C.E. 1960. Compression of dehydrated foods. In "Nutritional evaluation of food processing," Eds. , Harris, R. and Van Loesecke, H. pp 159-161. John Wiley, New York.

38. Hollender, H.A. 1975. Convenience or fabricated foods: Spin-off of military R&D. Cereal Foods World 20(11): 530-532.

39. Hollender, H.A. and Klicka, M. 1965. Development of dehydrated and bite-sized food items. Aerospace Medical Research Laboratories Technical Report 65-160.

40. Hruzek, G.A. 1973. The quality of freeze-dried and compressed green beans and carrots. J. Rio Grande Valley Hort. Soc. 28:71.

41. Jayaraman, K.S., Das, S.A., Romanathan, L.A., and Bhatia, B.S. 1970. Development of some ready-to-eat compressed food formulation using deep-fat fried ingredients. J. Food Sci. Technol. (Mysore) 7(4): 200-202.

42. Jayaraman, K.S., Goverdhanan, T., San Kavan, R., Bhatia, B.S. and Nath, H. 1974. Compressed ready-to-eat fruited cereals. J. Food Science Technol. (Mysore) 11(4): 181.

43. Jones, R.L. 1975. Process development of limited freeze-drying. Ph.D. dissertation in Chemical Engineering, University of California, Berkley.

44. King, C.J., Carn, R.M., and Jones, R.L. 1976. Processing approaches for limited freeze-drying. J. Food Sci. 41:612-618.

45. Kumar, M. 1974. Swelling stress and hydrostatic compressibility of ground corn and its constituents. J. Food Sci. 39: 234-238.

46. Larson, R.W. 1971 Development of compressed, nonsweet, flavored snack foods to be used in the APOLLO food system. Final Report. 5 Jan 70 - 30 April 71. Whirlpool Corp., St. Joseph, Mich. Life Support Systems Group.

47. MacPhearson, B. 1973. Compression of cooked freeze-dried carrots. M.S. Thesis, Texas A&M University, College Station, Texas.

48. Magoon, C.A. 1948. Compression and storage of dehydrated foods. Food Inds. 20:384-6, 496, 498.

49. Mickus,R. R. and White, W.H. 1945. Compression helps to solve Army ration problems. Food Inc. 17:1147.

50. Moronov, N.V. and Nepomnuashchii, O.V. 1970. Experimental study of food briquette. Izvestiya Vysshikh Uchebnykh Zavedenii Pish. Tech. 4:100-103 (Russian).

51. Partridge, S.M., Lear, W.E., and Westall, R.G. 1944. Dried meat. VI. The effect of water content on the compression characteristics of dried meat. J. Soc. Chem. T63:16-18.

52. Popvskkii, V.G., Ivasyak, N.T., and Berezovskaya, S.N. 1973. Fruitberry blocks with sugar powder. Tr. Vses. Nauchni-issledovatle' skikh Inst. Konservn Cveshchesush, Prom - Sti 19:93 (Russian)

53. Prater, A.R. 1953. Compression of dehydrated mutton slices. Aus. J. Appl. Sci. 4_603-611.

54. Prater, A.R., Coate, G.G., and Roberts, E.A. 1960. Compression of dehydrated mutton and beef mince, J. Sci. Food Agr. 11:311.

55. Proctor, B.E. and Sluder, J.C. 1943. The compression of dehydrated foods. Proc. Inst. Food Technol. 132-143.

56. Rahman, A.R. 1973. Food of tomorrow - compressed foods. Food Processing. Vol 35:F4.

57. Rahman, A.R., Bishov, S., and Westcott, D.E. 1971. Reversible compression of dehydrated peas. J. of Texture Studies 2:240-245.

58. Rahman, A.R., Henning, L., Bishov, S., and Westcott, D.E. 1972. Increased density for military foods. Army Science Conference Proceedings, Vol. 3, Office, Chief of Research & Development, Department of the Army, Washington, DC AD 750368.

59. Rahman, A.R., Henning, W.L., and Westcott, D.E. 1971. Histological and physical changes in carrots as affected by blanching, cooking, freezing, freeze-drying and compression. J. Food Sci. 36: 501-502.

60. Rushing, J.E. 1975. Effects of temperature, moisture and soluble solids on rehydration fragmentation and texture of freeze-dried, compressed carrot bars. M.S. Thesis. Texas A&M University, College Station, Texas.

61. Rushton, E. et al. 1945. Compressed dehydrated vegetable block. U.S. Agr. Res. Admin. Report. PB 81586.

62. Rushton, E., Stanley, E.C., and Scott, A.W. 1945. Compressed dehydrated vegetable blocks, the application of high frequency heating. Chem & Ind. 23:274-276.

63. Sarkisyan, Z.A., Ivasyuk, W.T., and Popovskii, V.G. 1970. Briquetting of freeze-dried fruit puree and squash. Sbornik Nauchno - Issledovalel' skikh Pabot MNIPP 10:104 (Russian).

64. Self, N., Ralley, H.L.J., and Joyce, A.E. 1958. Fruit bar report covering period 1956-1958. Unclassified Report SA/DA/RM/86. Ministry of Agric., Fisheries and Food. Great Britain.

65. Shama, F. and Sherman, P. 1973. Stress relaxation during force-compression studies on foods with the Instron Universal testing machine and its implications. J. Texture Studies 4:353.

66. Treadway, R.H., Wagner, J.R., Woodward, C.F., Heisler, E.G., and Hopkins, R.M. 1958. Development and evaluation of potato chip bars. Food Technol. 12: 479-482.

67. Weisenfelder, A.E., Huffman, V.L., Smith, M.C., Heidelbaugh, N.D., and Burns, E.E. 1976. Freeze-dried and compressed food: A survey of the literature. The Texas Agricultural Experiment Station Bulletin MP-1271.

68. Wisakowsky, E.E., Burns, E.E., and Smith, M.C. 1977. Factors affecting the quality of freeze-dried compressed spinach. J. Food Sci. 42: 782-783, 794.

69. Younger, C.F.A. and Fairbrother, J.C 1968. The compression of instant bread mix. Food Technol. in Australia. 20: 276-279.

PATENTS

Adams, N.M. 1948. Compressing dehydrated foods. US Patent 2,445,752.

Asselbergs, E.A.M. 1966. Cooked dehydrated fish product. US Patent 3,201,260.

Barbini, S. 1971. Compressed tablets of freeze-dried foods. French Patent 2,052,151.

Berg, I.A. 1948. Compressed Cereal. US Patent 2,437,150.

Corey, H., Bakal, A., Konigsbacher, K. and Schoenholz, D. 1974. Compressed compounded food product and method of making same. US Patent 3,812,268.

Donnelly, J.C. 1947. Debulking food for packaging. US Patent 2,433,348.

Dryg, W.R. and Standing, C.N. 1974. Continuous process for preparing relatively dense bakery goods. US Patent 3,787,597.

Durst, J.R. 1969. Food bar with oil or fat binder. US Patent 3,431,112.

Durst, J.R. 1969. High protein food bar. US Patent 3,434,843.

Eskew, R.K. and Cording, J., Jr. 1968. Process for manufacturing rapidly rehydratable dehydrated fruits and vegetables of high density. US Patent 3,408,209.

Harris, N.E. 1973. Coated, dehydrated compressed foods. US Patent 3,726,693.

Ishler, N.H. and Knipper, A.J. 1968. Process for producing compressed, dehydrated cellular foods. US Patent 3,385,715.

Isherwood, F.A. 1944. Preservation and storage of perishable materials. C.A. 40:4119. Brit. Patent 561,966.

Japan Gify Food Co. 1966. A method for producing cube-shaped freeze-dried fruit juices. Japan 342/66.

Jokay, L. 1964. Dehydrated, carbohydrate-enriched, palatable cheese-based food bar. US Patent 3,121,014.

Jones, G.V., Pereira, J.A. and Rehman, W.C. 1975. Coffee percolator packages and method. US Patent 3,888,999.

Mancusio, J.J., Bonagura, A.G. and Sorgo, R.M. 1970. Compressed dehydrated bread. US Patent 3,512,991.

Marshall, D.E. 1952. Compacting pulverized materials. US Patent 2,594,956.

Mech, P.J., Gronski, R.W., and Smith, T.A. 1967. All-purpose matrix for use in a large variety of food bars. US Patent 3,336,139.

Morgan, J.E. 1974. High protein food bar. US Patent 3,814,819.

Ode, V.H. 1975. Method for producing a coherent ready-to-eat food unit comprising a bar of toasted granola cereal bound by the presence of a sweetened low-moisture whole milk product. US Patent 3,903,308.

Rahman, A.R. and Schafer, G. 1972. Directly edible compacted and dehydrated fruit bars. US Patent 3,705,814.

Rahman, A.R. 1974. Method for making a compressed, freeze vacuum dehydrated blueberry product of increased density (6-14 fold). US Patent 3,806,610.

Rahman, A.R. and Schafer, G.R. 1976. Method of producing compacted, dehydrated, vegetable products of increased density. US Patent 3,950,560.

Rahman, A.R. 1976. Method of compacting and freeze-drying particulate foods. US Patent 3,984,577.

Schafer, G.R. and Rahman, A.R. 1975. Directly edible and rapidly rehydratable compacted and dehydrated food bar. US Patent 3,882,253.

Schwartzberg, H. 1969. Fritted slab freeze-drying. US Patent 3,468,672.

Military Specifications and Limited Production Purchase Descriptions

Beans, Green, Dehydrated, Compressed	MIL-B-43930
Cereal, Premixed, Compressed	MIL-C-3483C
Corn Flake Bar, Survival-type	MIL-C-35074E Amend 2
Fruitcake Bar	MIL-F-3897C Amend 4
Fruits, Freeze-dehydrated	MIL-F-43559
Onions, Dehydrated, Compressed	MIL-O-43901 Amend 1
Peas, Dehydrated, Compressed	MIL-P-43873
Spinach, Dehydrated, Compressed	MIL-S-43877

Apples, Dehydrated, Compressed	LP/P DES 7-74
Beef, Diced, Dehydrated, Cooked, Compressed	LP/P DES 1-73
Cabbage, Dehydrated, Compressed	LP/P DES 7-76
Carrots, Dehydrated, Compressed	LP/P DES 3-75
Cherries, Dehydrated, Red, Tart, Pitted, Compressed	LP/ DES 5-74
Chicken, Diced, Dehydrated, Cooked, Compressed	LP/P DES 8-74
Corn, Yellow, Dehydrated, Compressed	LP/P DES 14-74
Fruits, Freeze-dehydrated, Flexibly Packaged	LP/P DES 29-74A
Vegetables, Mixed, Dehydrated, Compressed	LP/P DES 3-77

Table 1. Cross reference listing of technical reports on freeze-dried and compressed foods by year of publication.

Year of Publication	Technical Report Reference Numbers
1976	54
1975	20, 25, 39, 43
1974	12, 19, 20, 40, 47, 51, 53
1973	22, 25, 41
1972	3, 11, 13, 42
1971	15, 17, 33, 45, 55, 64
1970	38, 50, 56, 57, 59
1969	2, 9, 16, 21, 32, 37, 44, 46, 48, 49, 63
1968	30, 58, 65
1967	8, 27, 31, 34
1966	5, 6, 7, 10, 26
1965	4, 18, 23, 28, 29, 35, 36, 52, 67
1964	No technical reports in subject area
1963	No technical reports in subject area
1962	1, 13, 61, 62, 66
1961	14, 60

Table 2. Cross reference listing of technical reports on freeze-dried and compressed foods by food category.

Food Item	Technical Report Reference Numbers
I. Beef Products	
Beef, Barbecued	2, 6, 8
Beef and Barley	2, 18
Beef in Cheese Sauce	2, 8
Beef, Crackers, Eggs	36
Beef, Creamed, Ground	2, 6, 8, 18
Beef, Diced, Raw	4, 23, 29, 31, 40, 41, 42, 62
Beef, Diced, Cooked	2, 8, 24, 26, 29, 39, 41
Beef and Eggs	28
Beef and Gravy	2, 8
Beef, Ground, Cooked	4, 8, 17, 24, 35, 39
Beef, Ground, Beefsteak	10
Beef Hash	7, 20, 55, 59
Beef Jerky	16
Beef, Meatballs	24, 51
Beef and Noodles	43
Beef and Noodle Soup	18, 55
Beef with Onion Gravy	39
Beef, Patties, Raw	54, 56
Beef, Patties, Cooked	54
Beef and Potatoes	7, 28
Beef with Potatoes and Gravy	2, 8
Beef with Rice, Ground	6, 55, 59
Beef with Rice and Peas	27
Beef, Sliced, Raw	32
Beef, Sliced, Cooked	4, 19, 32, 60, 61, 65, 66
Beef and Spinach	28
Beef, Steak, Raw	4
Beef Stew	2, 6, 8, 18, 23, 24, 26, 33, 37, 58, 59
Beef Stroganoff	2
Beef in Tomato Sauce	2, 8
Beef and Vegetables	2, 5, 8, 20, 55
Chili Con Carne	2, 6, 18, 20, 23, 24, 37, 39, 55, 59
Spaghetti with Meat Sauce	55, 57, 59, 63, 64
II. Beverages	
Apricot Nectar	18
Butterscotch Drink	8
Chocolate Drink	8, 18, 38
Citrus Fruit Drink	38

Table 2 (continued)

Food Item	Technical Report Reference Numbers
II. Beverages (continued)	
Coffee with Cream and Sugar	6, 18
Lemon Drink	2
Lemonade	39
Orange Drink	2
Orange Juice	5, 6, 18, 28
Tea	18
III. Cereal Products, etc.	
Barley with Beef	2, 6, 18
Cereal	35
Corn Flakes	7, 15, 43, 55
Flour	28
Flour and Egg	10
Macaroni	26
Noodle and Beef Soup	10, 55
Noodle, Tuna, Mushroom Soup	33
Noodle Vegetable Soup	18
Oat	7
Oatmeal	54
Peanut	6, 18, 36
Soy Cracker	36
Spaghetti with Meat Sauce	55, 57, 59, 63, 64
Special K	21
Wheat Flake	7
IV. Dairy Products	
Buttermilk	18
Cheese	2
Cheese, Cottage	5, 21, 23, 26, 33
Cheese, Cottage and Pineapple	38
Cheese, Gouda	18
Cheese, Romano	6
Cheese Sauce	8
Cheese Sauce, Beef in	2, 8
Cheese Sauce, Tuna in	8
Cheese with Vegetables and Bacon	8
Milk, Nonfat, Dry	5, 8, 10, 18, 29, 35, 36
Sour Cream	2
Welsh Rarebit	18, 38

Table 2 (continued)

Food Item	Technical Report Reference Numbers
V. Fruits	
Apples	10, 25, 26, 28, 29
Applesauce	5, 47
Apple and Strawberry	28
Apricot	22, 30
Banana	30
Blueberries	50
Cherries	25, 43, 50, 53, 55
Dates	18, 35
Date-Cherry	45
Date-Fig	45
Date-Fig-Almond	45
Date-Sesame	45
Fig-Cherry-Pear-Orange	45
Lemon	2
Orange	2
Peaches	6, 18, 21, 22, 23, 28, 30, 32
Pears	22
Pineapple	27, 30, 33
Prunes	28
Raisin	6, 27, 29, 45
Strawberries	22, 23, 26, 27, 28, 30
VI. Gravies	
Brown	2, 8
Chicken	8
Homestyle	8
Poultry	2
VII. Miscellaneous	
Cake, Pound	26
Caramel	27
Chocolate Bar	6, 18
Coconut	36
Cookie, Lorna Doone	18
Cookie, Monileavened	27
Cookie, Sugar	6
Cracker, Graham	6, 18
Crust, Pie	6, 18, 50
Fruit Preserves	6, 18
Lemon Candy	2

Table 2 (continued)

	Food Item	Technical Report Reference Numbers
VII.	Miscellaneous (continued)	
	Orange Candy	2
	Pancake	26
	Potato Chips	35
	Salad Dressing	2
	Zwieback	26
VIII.	Pork Products	
	Bacon with Eggs, Scrambled	37
	Bacon, Prefried	2, 4, 8, 19, 36
	Bacon and Rice	36
	Bacon, Rice and Egg	10
	Bacon with Vegetables and Cheese	8
	Franks and Beans	20, 55
	Ham with Creamed Vegetables	37
	Pork, Barbecued	2, 37, 39
	Pork in Cheese Sauce	8
	Pork Chops, Cooked	55
	Pork Chops, Raw	3, 4, 11, 54
	Pork, Diced	2, 8, 37, 39, 59
	Pork and Gravy	2, 8
	Pork with Potatoes	54, 59
	Pork, Potatoes, and Gravy	2, 8
	Pork, Rice, and Gravy	2, 8
	Pork Sausage	9, 51, 54
	Pork Stew	8
	Pork Stroganoff	2
	Pork in Tomato Sauce	2, 8
	Pork and Vegetables	2, 8
IX.	Poultry Products	
	Chicken	6, 18, 26, 29
	Chicken a la King	2, 6, 19, 37
	Chicken, Barbecued	2, 8
	Chicken, Cream of	12
	Chicken, Curried	39
	Chicken, Diced	2, 8, 21, 23, 24, 33, 36, 52, 54, 67
	Chicken and Gravy	2, 8
	Chicken Noodle Soup	12, 18

Table 2 (continued)

	Food Item	Technical Report Reference Numbers
IX.	Poultry Products (continued)	
	Chicken, Potatoes, and Gravy	2, 8
	Chicken and Rice	5, 18, 20, 24, 37, 55, 59
	Chicken, Rice and Gravy	2, 8
	Chicken Salad	2, 8
	Chicken Stew	8, 21, 58, 59
	Chicken Stroganoff	2
	Chicken and Vegetables	8, 20, 55
	Eggs, Bacon, and Rice	10
	Eggs and Beef	28
	Eggs and Flour	10
	Eggs, Precooked	6
	Eggs, Scrambled	18, 23, 34
	Eggs, Scrambled with Bacon	37
	Eggs and Spinach	28
	Mayonnaise	8
	Turkey a la King	2
	Turkey, Barbecued	2, 8
	Turkey, Diced	2, 8
	Turkey and Gravy	2, 8
	Turkey, Potatoes and Gravy	2, 8
	Turkey, Rice, and Gravy	2, 8
	Turkey Salad	2, 8
	Turkey Stew	8
	Turkey Stroganoff	2
	Turkey and Vegetables	2, 8
X.	Puddings and Pie Fillings	
	Banana Cream	18
	Butterscotch	8
	Chocolate	5, 8, 18, 39
	Fruit Pie Filling	6
	Lemon Pie Filling	6
	Pineapple Fruit	38
	Plum	18
	Tapioca, Pregelatinized	6, 18
XI.	Rice	
	Rice	2, 8, 23, 29, 36, 55
	Rice with Bacon	36
	Rice with Bacon and Eggs	10
	Rice with Beef	6, 55, 59
	Rice with Beef and Gravy	2, 8
	Rice with Beef and Peas	2
	Rice with Chicken	5, 18, 20, 24, 37, 55, 59

Table 2 (continued)

	Food Item	Technical Report Reference Numbers
XI.	Rice (continued)	
	Rice with Chicken and Gravy	2, 8
	Rice Krispies	7
	Rice with Pork and Gravy	2, 8
	Rice, Puffed	26, 27
	Rice with Shrimp	2
	Rice in Shrimp Creole	6, 18, 35
	Rice with Tuna	8
	Rice with Turk and Gravy	2, 8
XII.	Sauces	
	Barbecue	2, 8
	Chocolate	8
	Onion	2, 8
	Seafood	2
	White	2, 8
XIII.	Seafoods	
	Clam Chowder	18
	Cod	29
	Crabmeat Cocktail	38
	Fish, Raw	4, 18
	Fish Squares	54
	Herring	6
	Scallops	54
	Shrimp	2, 4, 10, 23, 24, 26, 29, 32, 54
	Shrimp Chowder	17
	Shrimp Creole	6, 18, 37
	Shrimp Newburg	2
	Shrimp and Rice	2
	Shrimp with Seafood Sauce	2
	Tuna	8,54
	Tuna in Cheese Sauce	8
	Tuna, Creamed	8
	Tuna, Noodle, Mushroom Soup	33
	Tuna and Potatoes	8
	Tuna and Rice	8
	Tuna Salad	8, 37
	Tuna in Tomato Sauce	8

Table 2 (continued)

Food Item	Technical Report Reference Numbers
XIV. Vegetables	
Asparagus	26
Beans, Green	46, 49
Beans, Lima	22
Bean Salad	43, 54
Cabbage	27, 28, 29, 32
Cabbage, Cole Slaw	38
Carrots	24, 27, 28, 32, 46, 52
Carrots and Cabbage	28
Corn	23, 30, 46, 48
Lettuce	30
Mushrooms	23
Mushroom Soup, Cream of	5, 6, 12, 18, 38, 39
Mushroom, Tuna, Noodle Soup	33
Onions	12, 23, 27, 46
Peas	33, 39, 44, 52, 66, 69
Peas and Corn	7, 10, 12, 21, 23, 26, 29, 30, 32, 35, 46
Peas, Rice, and Beef Soup	27
Pea, Split, Soup	18
Peppers, Green	26
Potatoes and Beef	28
Potatoes, Beef and Gravy	2, 8
Potatoes, Chicken and Gravy	2, 8
Potato Chips	35
Potato Flakes	10
Potato, Mashed	2, 5, 8, 28
Potatoes with Pork	60
Potatoes, Pork and Gravy	2, 8
Potato Salad, German	38
Potato Soup	2
Potato Soup with Beef	7
Potato Soup, Cream of	8
Potato and Tuna	8
Potatoes, Turkey, and Gravy	2, 8
Spinach	10, 23, 28, 29, 46, 52
Spinach with Beef	28
Tomato	12, 30
Tomato Juice Cocktail	6
Tomato Sauce	2, 8

Table 2 (continued)

Food Item	Technical Report Reference Numbers
XIV. Vegetables (continued)	
Tomato Sauce, Beef in	2, 8
Tomato Sauce, Pork in	2, 8
Tomato Sauce, Tuna in	8
Tomato Soup	18
Tomato Soup, Cream of	6, 8
Vegetable	2
Vegetables and Beef	2, 5, 8, 55
Vegetables with Cheese and Bacon	8
Vegetables and Chicken	8, 20, 55
Vegetables, Mixed, Creamed with Ham	37
Vegetables, and Noodle Soup	18
Vegetables and Pork	2, 8
Vegetables, Spring	12
Vegetables and Turkey	2, 8

Table 3. Cross reference listing of technical reports on freeze-dried and compressed foods by author.

Author	Technical Report Reference Numbers
Acree, T.E.	25
Anderson, E. A.	47
Battey, R. F.	29
Bauman, H. E.	1
Blodgett, J.	2
Brown, C.L.	3
Chipault, J. R.	4
Cole, M. S.	5
Cope, P.	52
Criz, P. S.	47
Do, Y. J.	53
DuBose, D.	43
Durst, J. R.	6, 7, 8
Egeland, C. A.	28
Farrier, R. D.	28
Fitzmaurice, W. J.	9
Ginette, L. F.	10
Goffi, E. A.	11
Gorfein, H.	12, 43
Gould, J. W.	13
Hamdy, M. M.	14
Harris, N.	15
Hawkins, J. M.	4
Helmer, R. L.	9, 16, 17, 58, 59, 63, 65
Hewitt, E. J.	18
Hinnergardt, L. C.	19, 20, 56, 57, 58, 59, 64
Hoge, H. J.	41, 42
Hollis, F., Jr.	21
Hsia, S. T.	22
Huang, E. A.	51
Ishler, M. I.	23
Johnson, K. R.	47, 48, 49
Kapsalis, J. G.	16
Kenyon, E. M.	13
Konigsbacher, K. S.	24
LaBelle, R. L.	25
Lampi, R. L.	26, 27, 28, 29
Lechnis, R. J.	60, 61, 62
Lennon, J.	28, 29

Table 3 (continued)

Author	Technical Report Reference Numbers
Luyet, B. J.	30, 31, 32, 33
Mackenzie, A. P.	31, 32, 33
Miller, K.	44, 48, 49
Miller, T.	60, 61, 62
Mink, L. D.	34
Mone, P. E.	34
Morris, E. R.	35, 36
Newlin, H. E.	36
Ogden, L. V.	63
Parks, T. R.	22
Pavey, R. L.	37, 38, 39
Peltre, P. R. F.	40
Perry, J. T., Jr.	13
Pilsworth, M. M., Jr.	41, 42
Powers, E. M.	12
Prell, P.	45
Rahman, A. R.	12, 43, 44, 45, 46, 47, 48, 49, 50
Randive, A. S.	51
Roth, N.	52
Salunkhe, D. K.	53
Schafer, G.	43, 44, 45, 46, 50
Schmidt, T. R.	47
Segars, R. A.	16, 42
Seltzer, E.	51, 54
Shafer, H. W.	3, 64
Sharma, S. C.	54
Sherman, D. E.	20
Sidel, J.	22
Sierra, S.	29
Srisangnam, C.	53
Stentz, R. L.	65
Takahashi, H.	28, 29
Taylor, G. R.	46, 48, 50, 51
Tuomy, J. M.	3, 9, 11, 16, 17, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66
Wells	67
Westcott	12, 16, 43, 45, 46, 51
Wheaton, R.	52
Young, R. G.	66

Table 4. Cross reference listing of journal articles and papers on freeze-dried and compressed foods by authors.

Author	Article or Paper Reference Number(s)	Year(s) of Publication
Anonymous	1-8	1942-1948
Bennet, R. G.	9	1977
Berezouskaya, S. M.	52	1973
Berlin, K.	10	1966
Bahtia	41, 42	1970, 1974
Bishov, S.	57, 58	1971, 1972
Brockmann, M. C.	11, 12, 13	1966, 1970, 1974
Burns, E. E.	9, 67, 68	1976, 1977
Carn, R. M.	14, 44	1972, 1976
Casey, J.	33	1958
Clowes, R. F.	15	1973
Coase, G. C.	54	1960
Curry, T. C.	16	1974
Dalgleish, J. M.	17	1953
Das, S. A.	41	1970
Dibbern, V.	18	1976
Do, J. Y.	19, 20	1975, 1976
Duckworth, R. B.	32, 33	1958
Dunlop, W. C., Jr.	21	1946
Emani, S. H.	22	1927
Fairbrother, J. G.	23-26, 69	1967, 1967
Ferrel, R. E.	27	1962
Flink, J. M.	22, 28	1977
Gilles, M. T.	29	1974
Goading, E. G. B.	30-35	1952-1962
Goneidhaman, T.	42	1974
Hay, J. M.	36	1958
Heisler, E. G.	66	1958
Hendel, C. E.	37	1960
Henning, L.	58, 59	1971, 1972
Heidelbaugh, N. D.	67	1976
Hollender, H. A.	38, 39	1965, 1975
Hopkins, R. M.	56	1958
Hruzek, G. A.	40	1973
Huffman, V. L.	67	1976
Iriasyuk, M. T.	52, 63	1970, 1973
Jayaraman, K. S.	41, 42	1970, 1974
Jones, R. L.	43, 44	1974, 1976

Table 4 (Continued)

Author	Article or Paper Reference Number(s)	Year(s) of Publication
Joyce, A. E.	64	1958
King, C. J.	44	1976
Klicka, M.	39	1965
Kliman, P. G.	10	1966
Kumas, M.	45	1974
Larson, R. W.	46	1971
Leas, W. E.	51	1944
MacDougall, D. G.	33	1958
MacPhearson, B.	47	1973
Magoon, C. A.	48	1948
Mickus, P. R.	49	1945
Morozon, M. V.	50	1970
Math, H.	42	1974
Mepomuuashchii, O. V.	50	1970
Olson, R. L.	27	1962
Pallausch, M. J.	10	1966
Partridge, S. M.	51	1944
Pence, J. M.	27	1962
Popreskhii, V. G.	52, 63	1970, 1973
Potewisatananond, S.	20	1976
Prater, A. R.	53, 54	1953, 1960
Proctor, D. E.	55	1943
Rahman, A. R.	9, 19, 20, 22, 56-59	1971-1977
Ralley, H. L. J.	64	1958
Rolfe, E. J.	34	1957
Romanathan, L. A.	41	1970
Ross, I. J.	15	1973
Roberts, E. A.	54	1960
Rushing, J. E.	60	1975
Rushtory, E.	61, 62	1945
Salunkhe, D. K.	19, 20	1975, 1976
Sankanan, R.	42	1974
Sarkisyan, Z. A.	63	1970
Scott, A. W.	62	1945
Self, R.	64	1958
Schama, F.	65	1973
Sherman, P.	65	1973
Shuler, J. C.	55	1943

Table 4 (Continued)

Author	Article or Paper Reference Number(s)	Year(s) of Publication
Smith, M. C.	67, 68	1976, 1977
Smith, S. W. C.	26	1968
Srisangnam, C.	19	1975
Stanley, E. C.	62	1945
Taylor, E. C.	27	1962
Treadway, M. B.	66	1958
Wagner, J. R.	66	1958
Weisenfelder, A. E.	67	1976
Westall, R. B.	51	1944
Westcott, D. E.	57, 58, 59	1971, 1972
White, G. M.	15	1973
White, W. H.	49	1945
Wisahowsky, E. E.	9, 68	1977
Woodward, C. F.	66	1958
Younger, C. F. A.	69	1968

This document reports research undertaken at the US Army Natick Research and Development Command and has been assigned No. NATICK/TR-78/016 in the series of reports approved for publication.